Using CERES Observations to Help Correcting Cloud 3D Radiative Effects on MODIS AOT Retrieval in the Vicinity of Clouds : A Case Study

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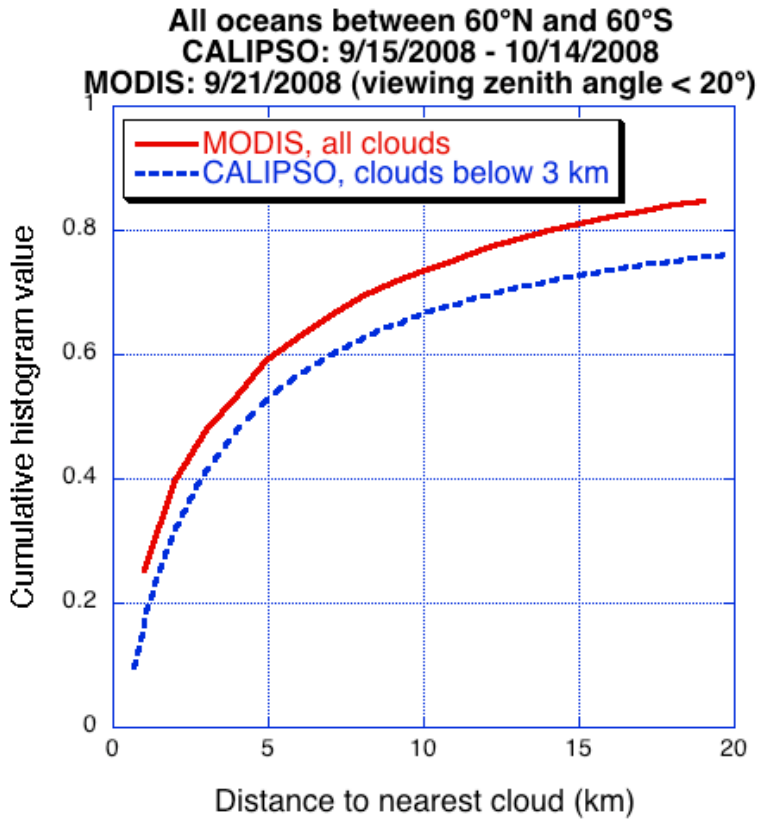
Clear areas near clouds

Motivation:

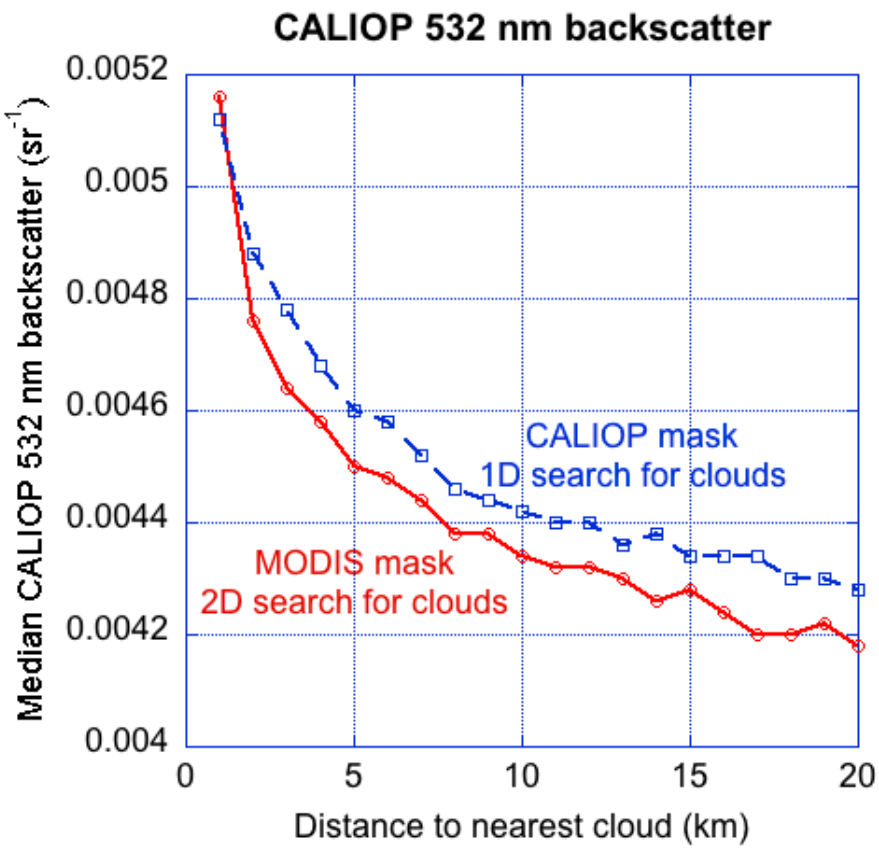
- Help satellite studies of aerosol-cloud interactions
- Aerosol remote sensing near clouds is challenging
- Excluding areas near-cloud risks biases in aerosol data

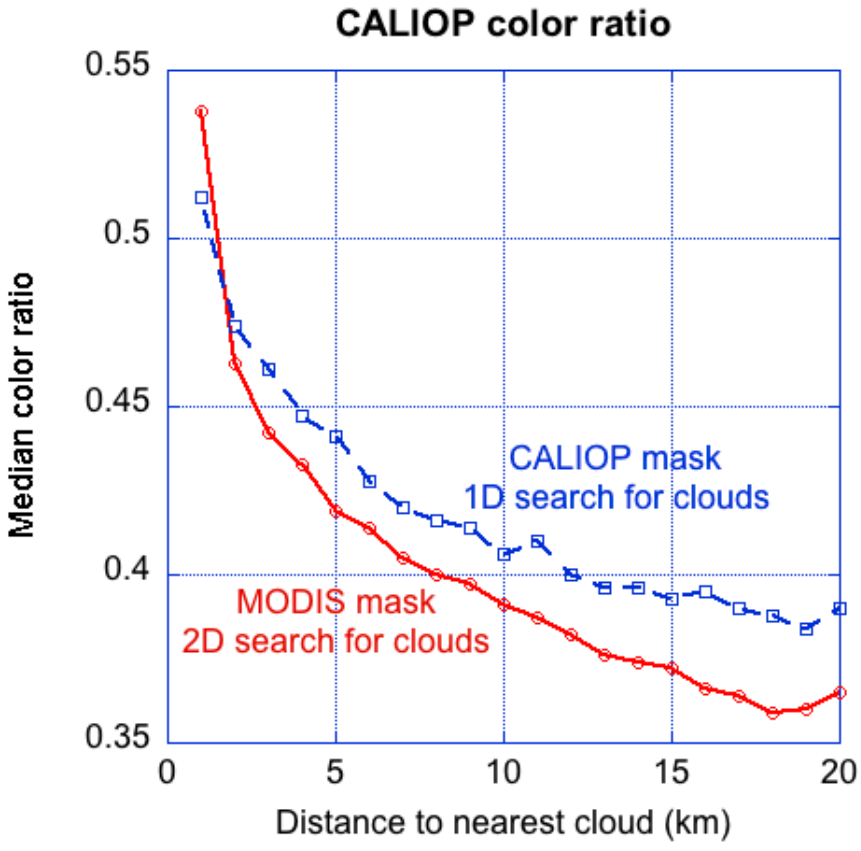


from **MODIS**: 60% of all clear sky pixels are located 5 km or less from all clouds

from **CALIPSO**: 50% of all clear sky pixels are located 5 km or less from low clouds

CALIOP vs. MODIS cloud mask

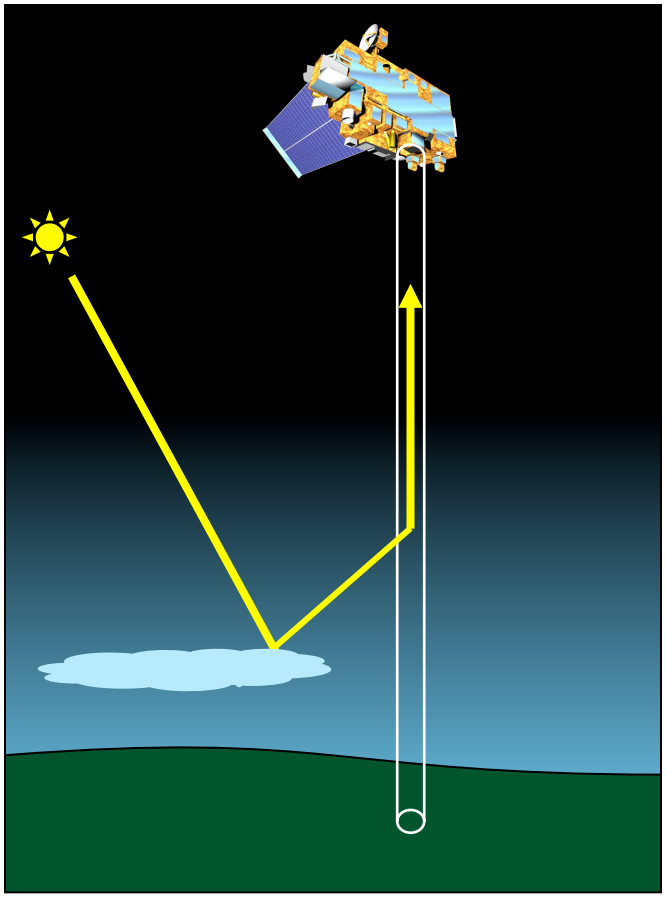




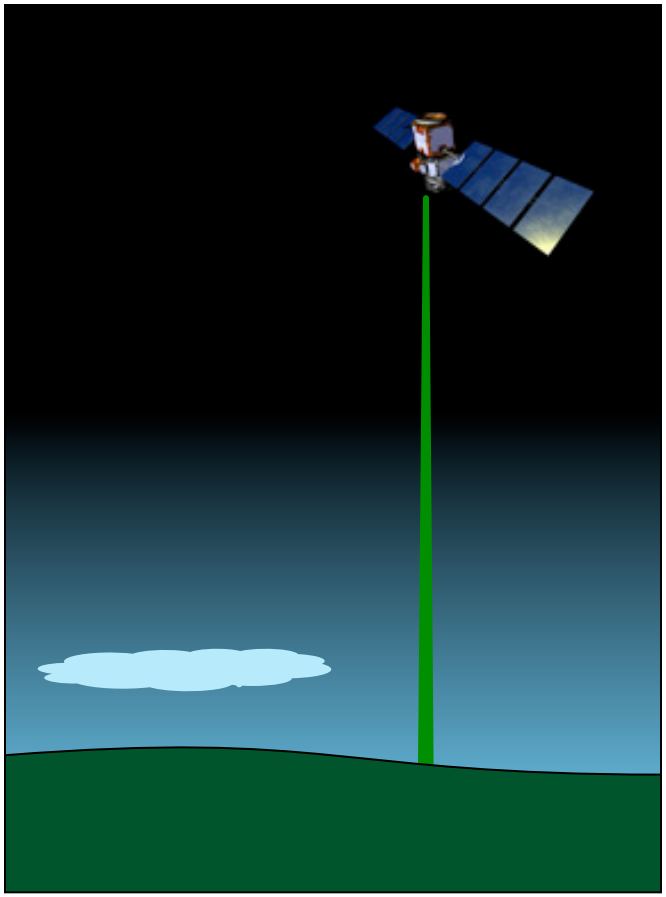
Behavior is similar using either cloud mask
Daytime data over oceans during April 2007

3-D: MODIS vs. CALIPSO

MODIS: 3D enhancement



CALIPSO: no 3D enhancement



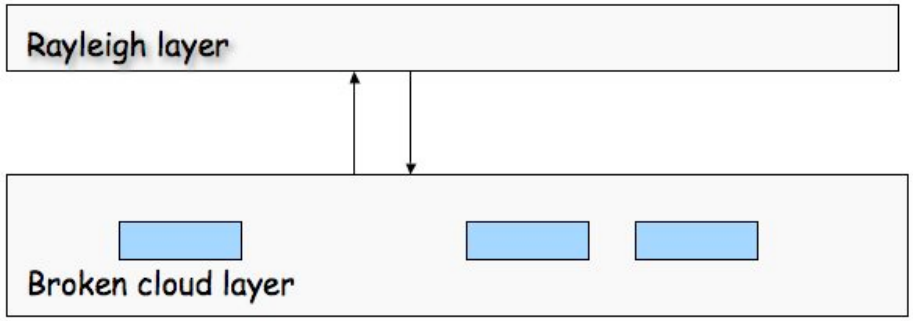
Simple Model for correction of 3D Radiative Effects

Inputs

- τ_m Rayleigh scattering
- F_{NB} upward flux

CERES obs can help to get F_{NB}

Two-layer model



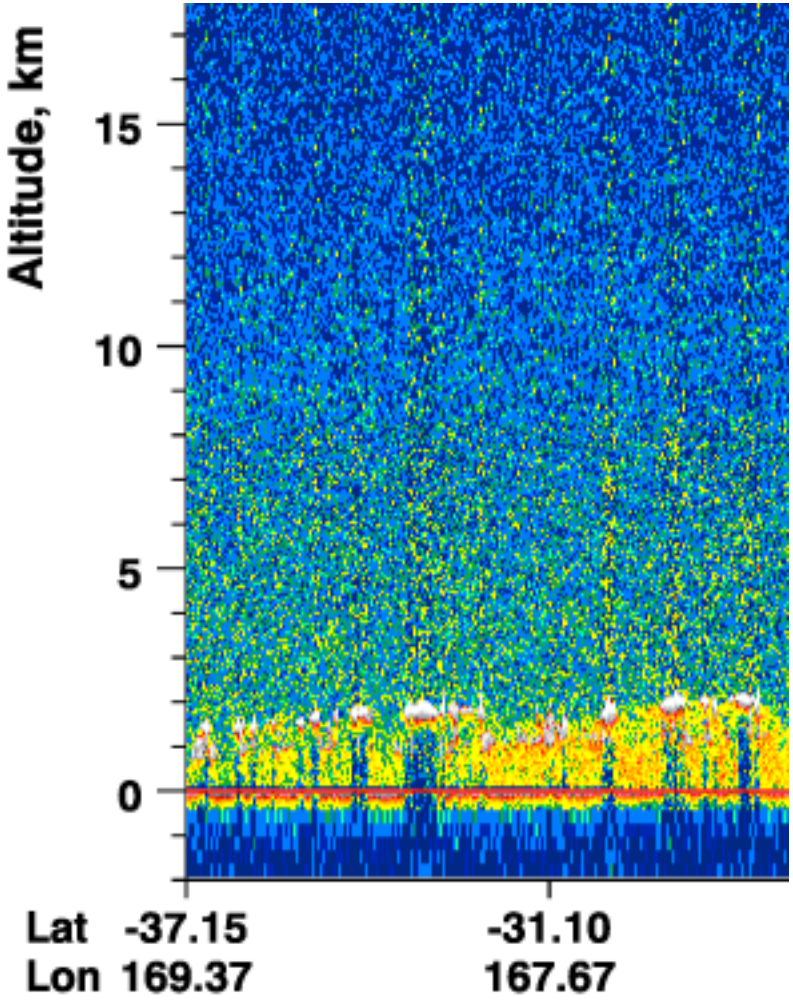
$$R_{COR} = R_{MODIS} - \Delta R$$

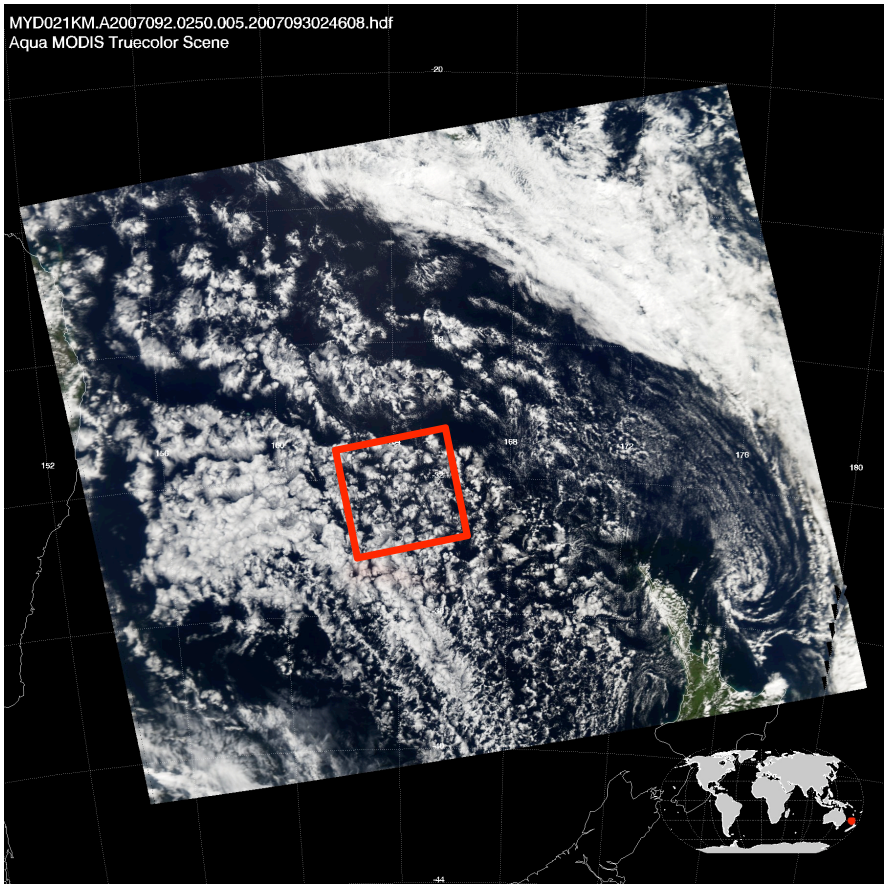
$$\Delta R = \Delta R(\tau_m, F_{NB})$$

Marshak et al. (2008)

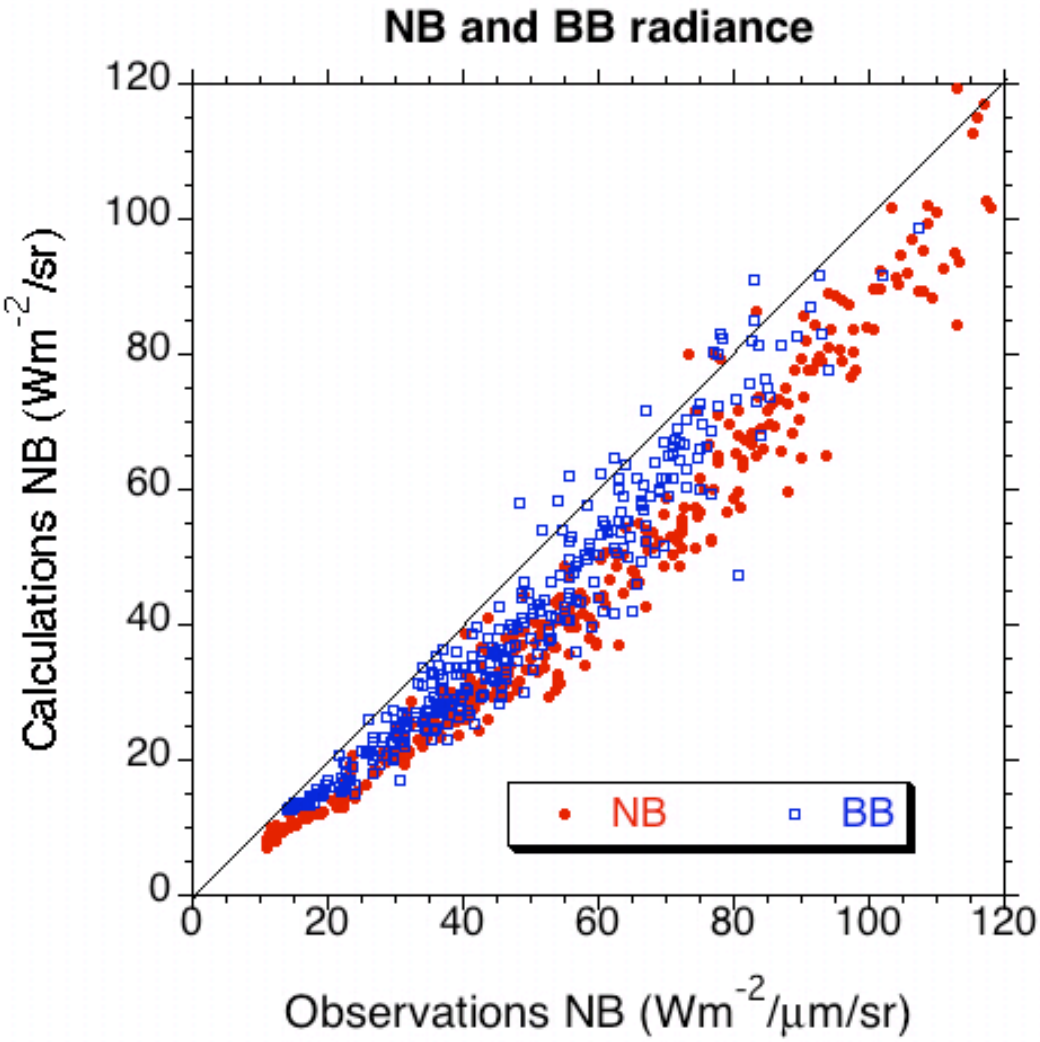
$\Delta R = 0$ if $F_{NB} = F_{NB\_clear}$

Application to Aqua MODIS

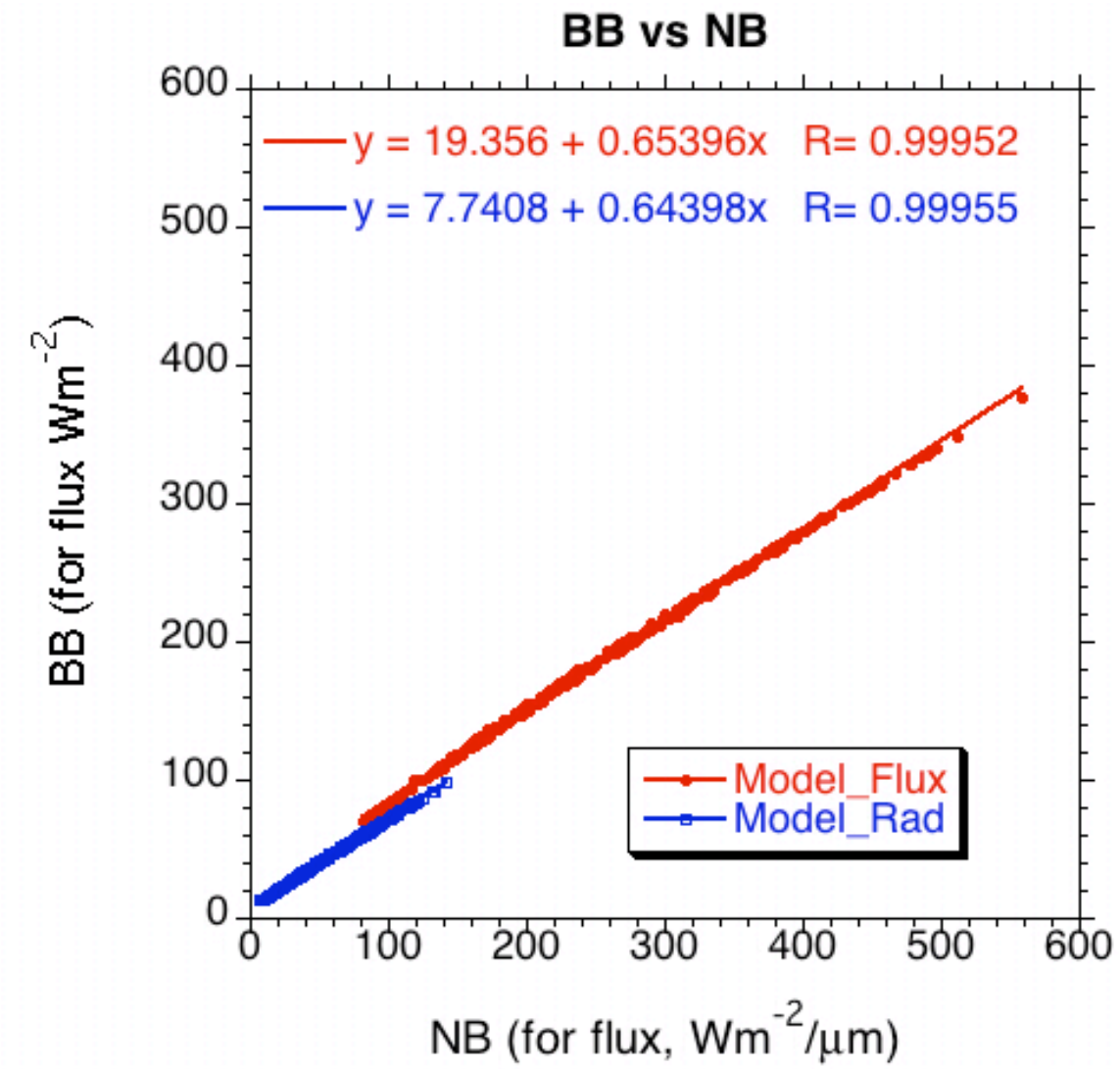




Plane-Parallel Bias



Linearity between NB and BB



How Can CERES Help?

Assume $\frac{F_{obs}^{NB}}{F_{obs}^{BB}} \approx \frac{F_{mod}^{NB}}{F_{mod}^{BB}}$ or

CERES

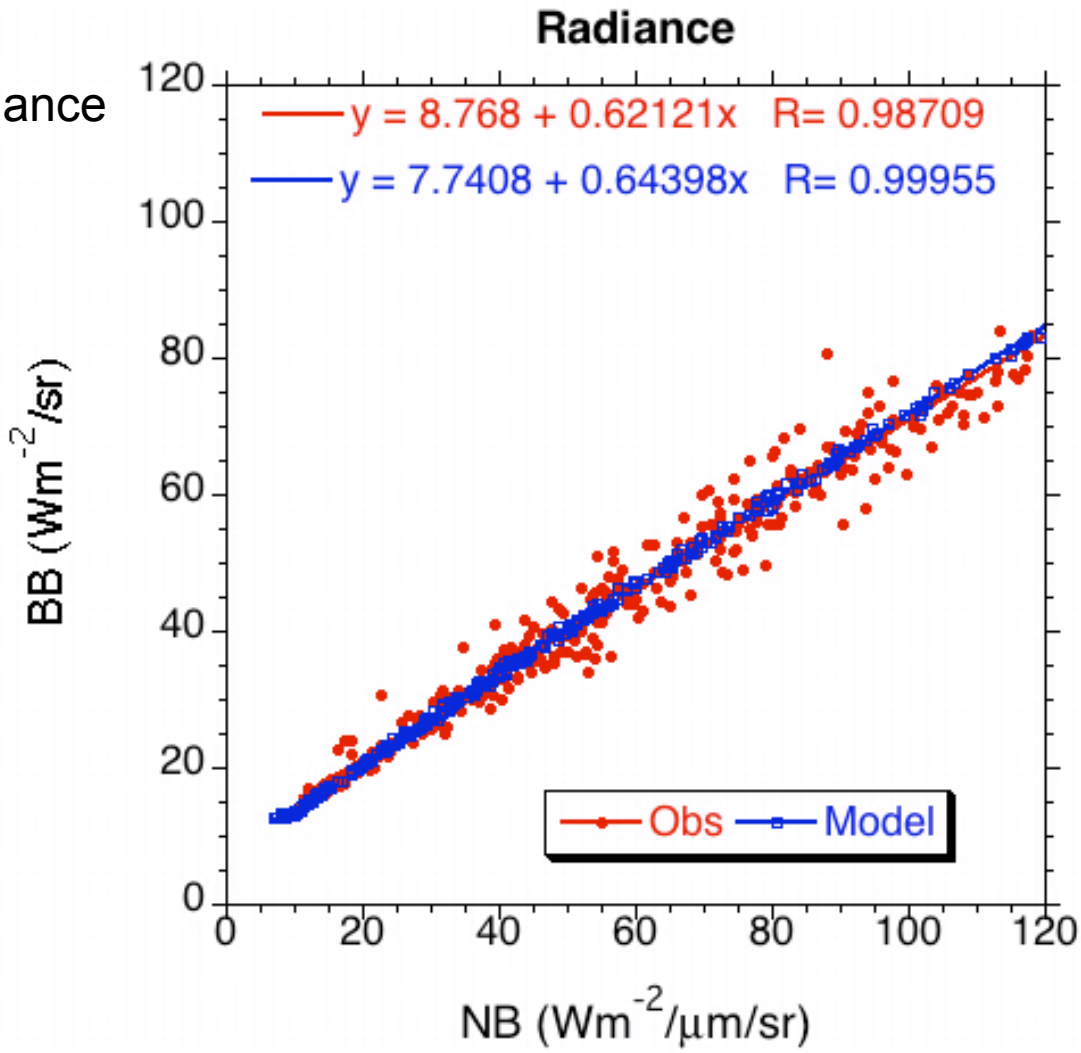
$$F_{obs}^{NB} \approx \frac{F_{obs}^{BB}}{F_{mod}^{BB}} \cdot F_{mod}^{NB}$$

RT model (τ, *f*, r_e)
Correlated-k for BB
Ocean BRDF
Input from CERES

Consistency Check

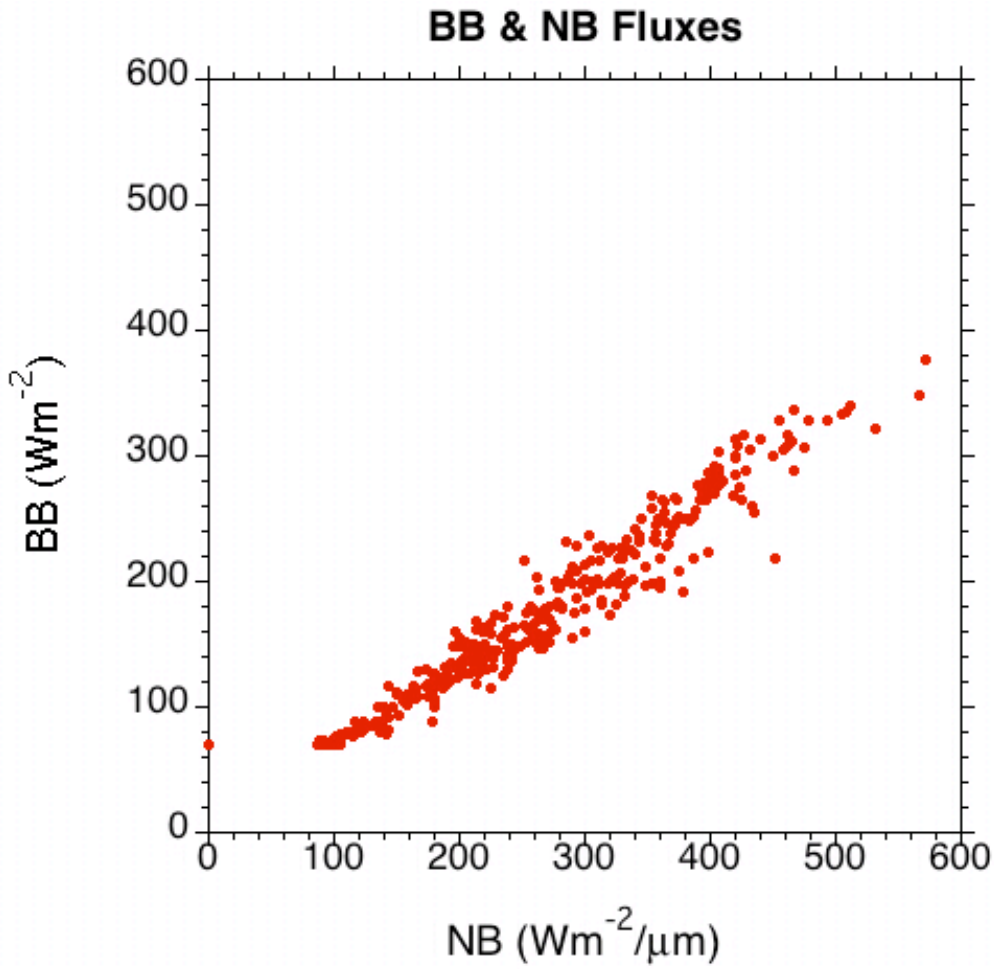
Check the assumption for radiance

$$\frac{F_{obs}^{NB}}{F_{obs}^{BB}} \approx \frac{F_{mod}^{NB}}{F_{mod}^{BB}}$$



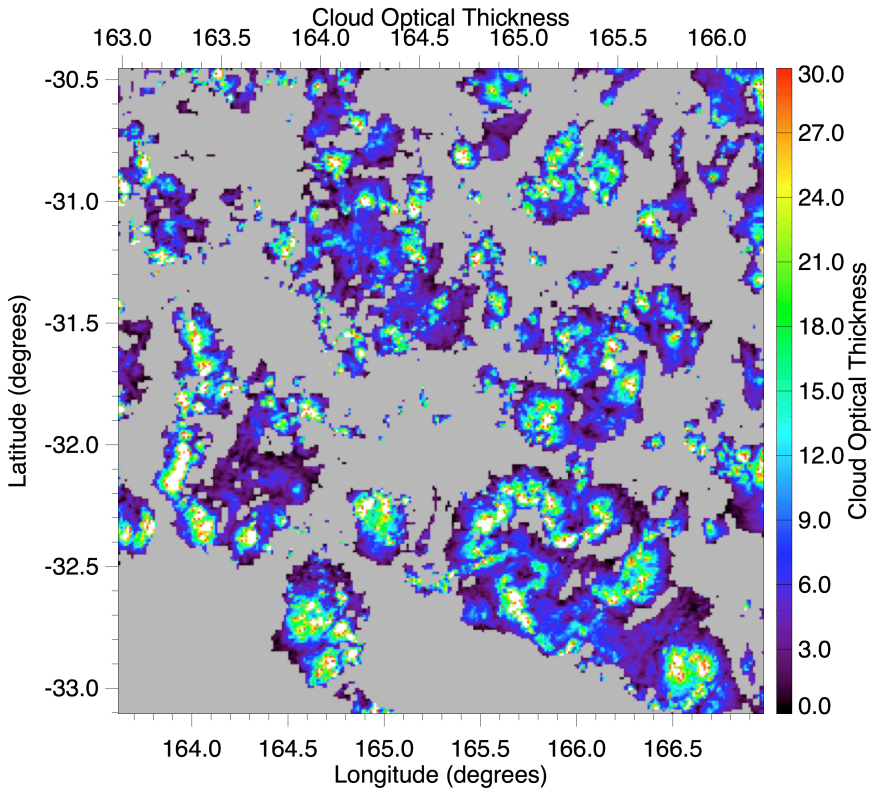
BB to NB Conversion

$$F_{obs}^{NB} \approx \frac{F_{obs}^{BB}}{F_{mod}^{BB}} \cdot F_{mod}^{NB}$$



Application to Aqua MODIS

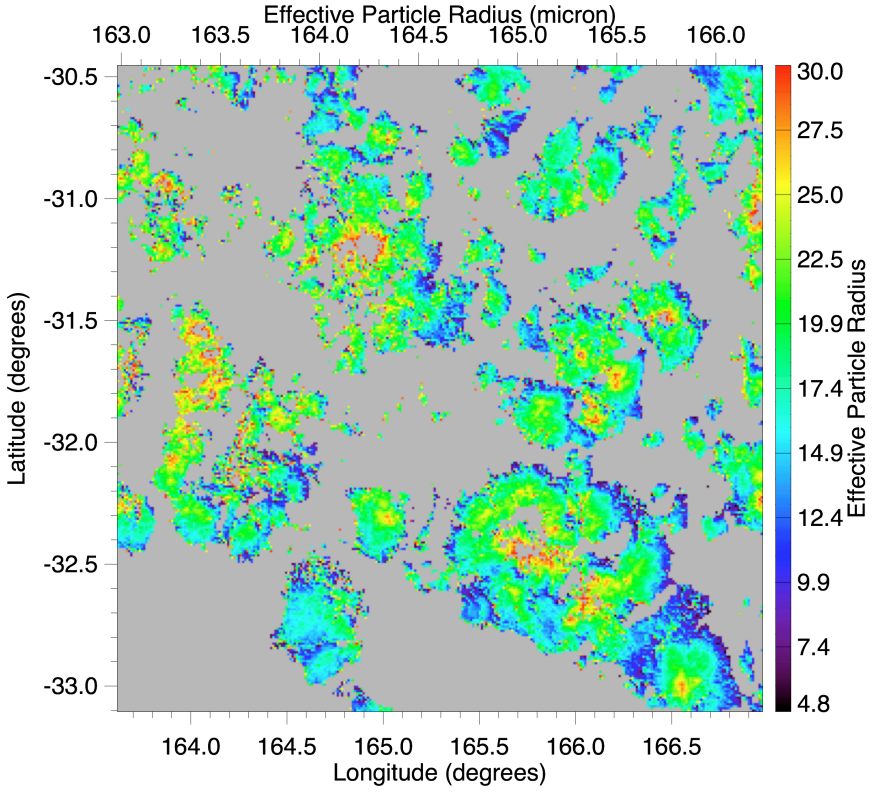
MODIS COD



300 km

Average(τ)=9
Stddev(τ)=9

MODIS Re

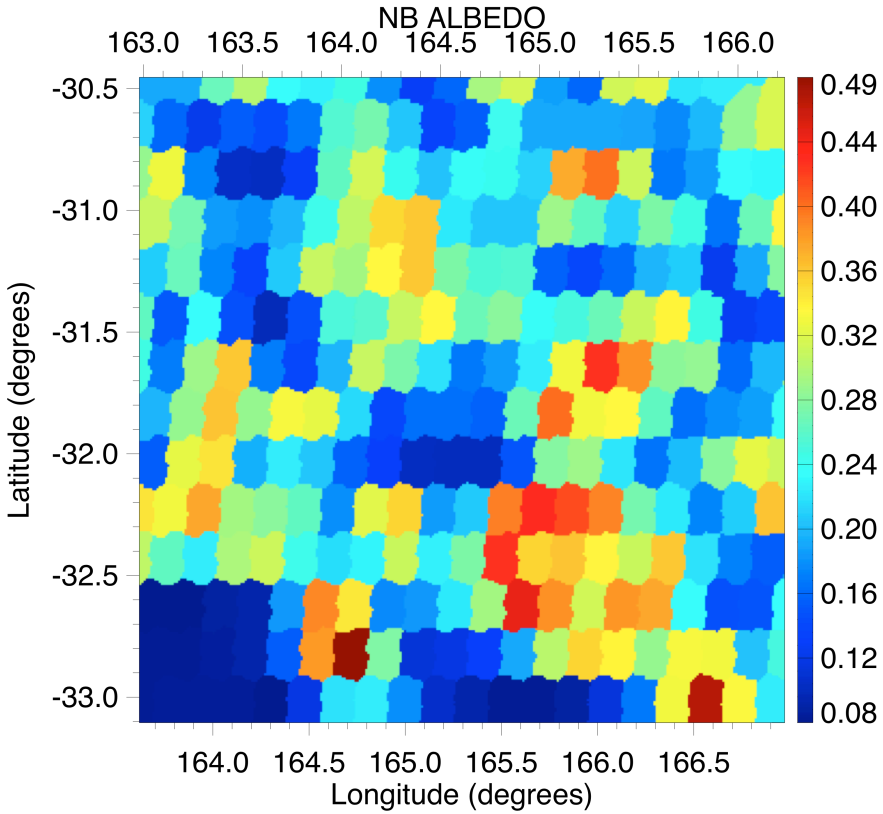


300 km

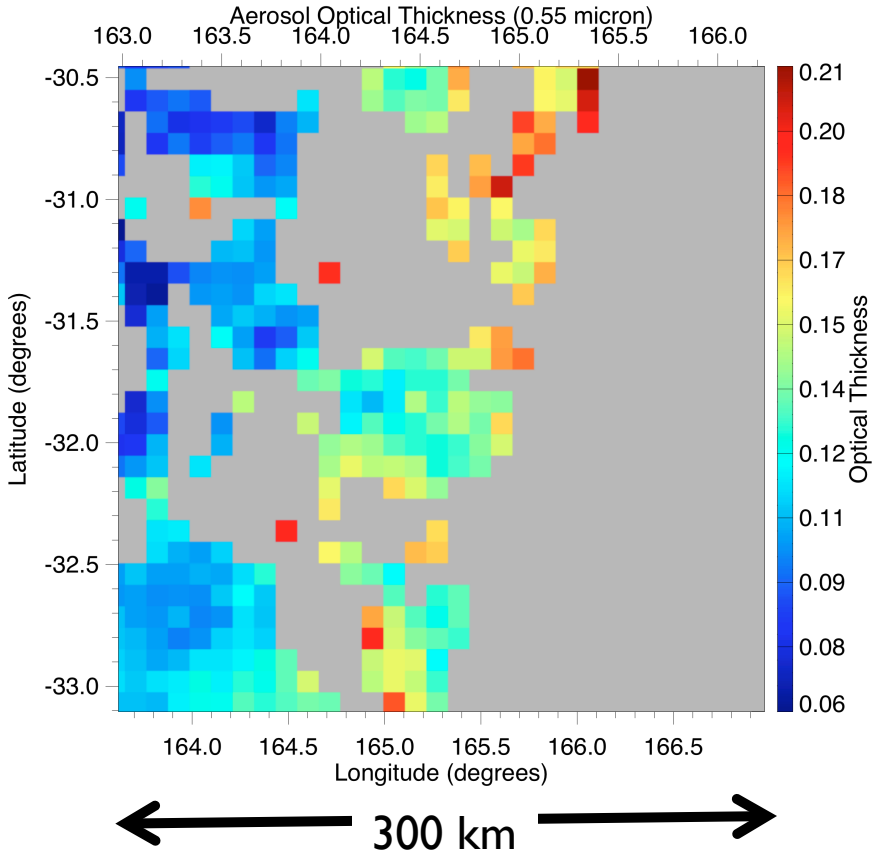
Average(R_e)=18 μm
Stddev(R_e) =5 μm

NB Albedo vs MODIS AOT

NB Albedo



MODIS AOT



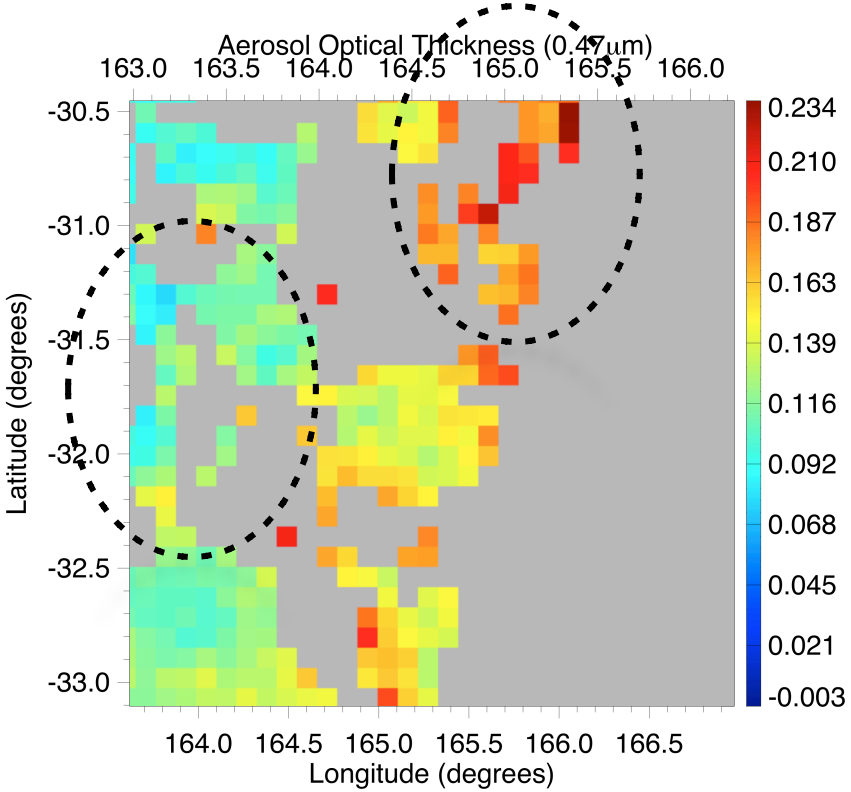
Albedo= $F\uparrow/(F_0*\cos(\theta_0))$

$F\uparrow$ Derived

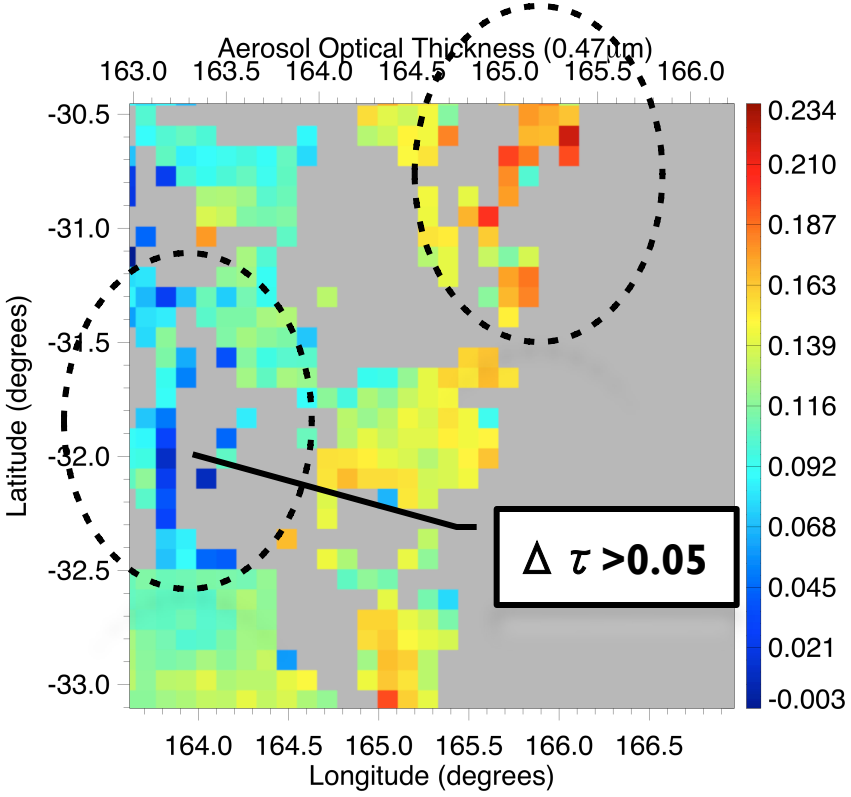
Average AOT ~0.13

Original vs corrected AOT

Original (0.47μm)

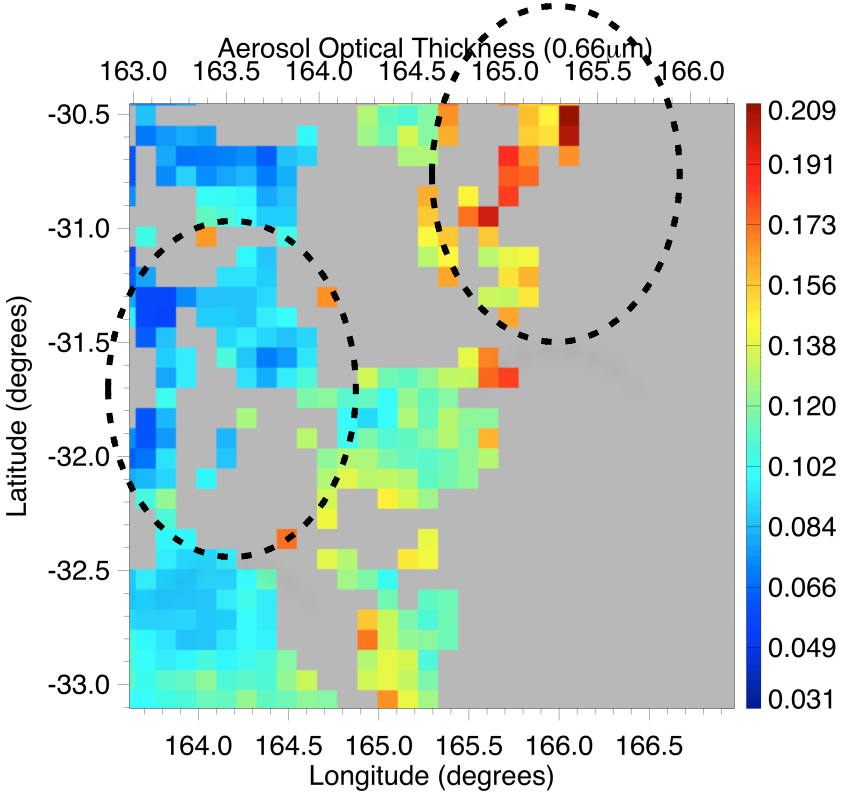


Corrected (0.47μm)

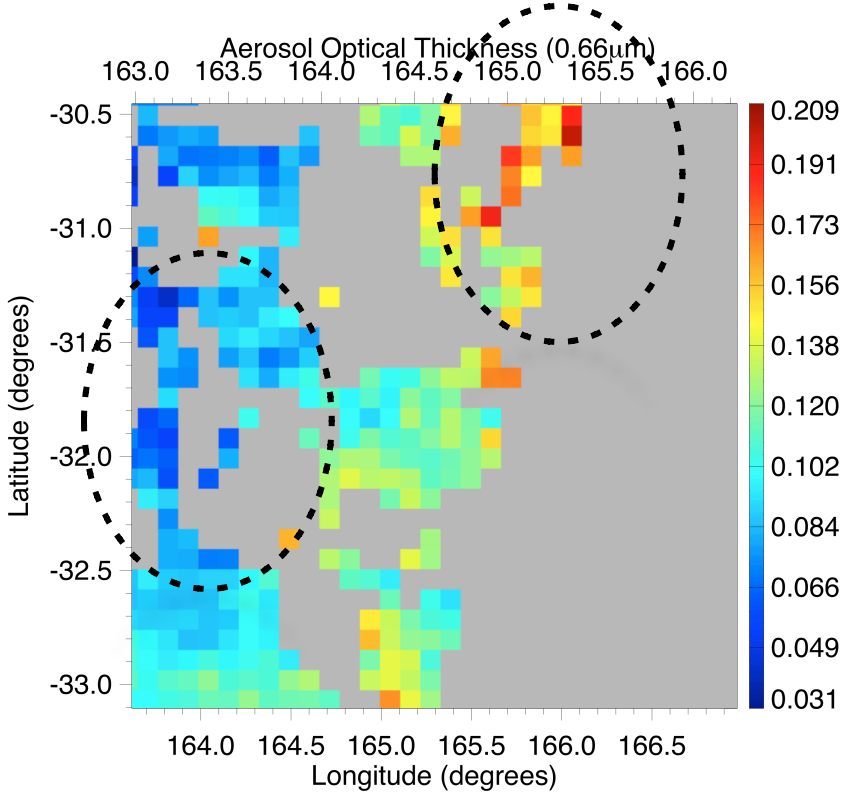


Original vs corrected AOT

Original (0.66μm)



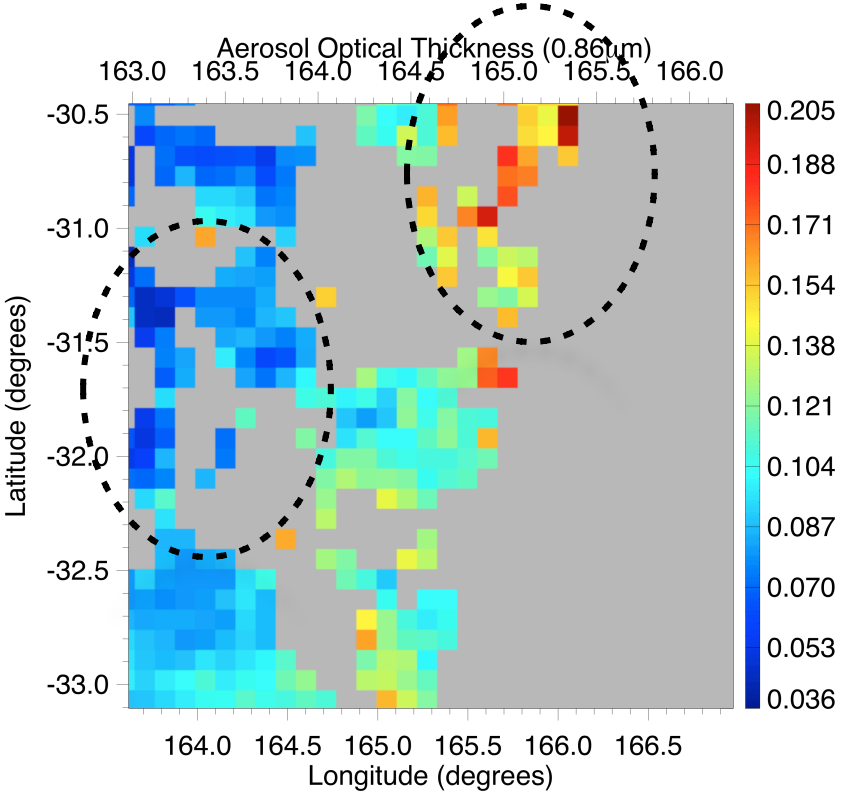
Corrected (0.66μm)



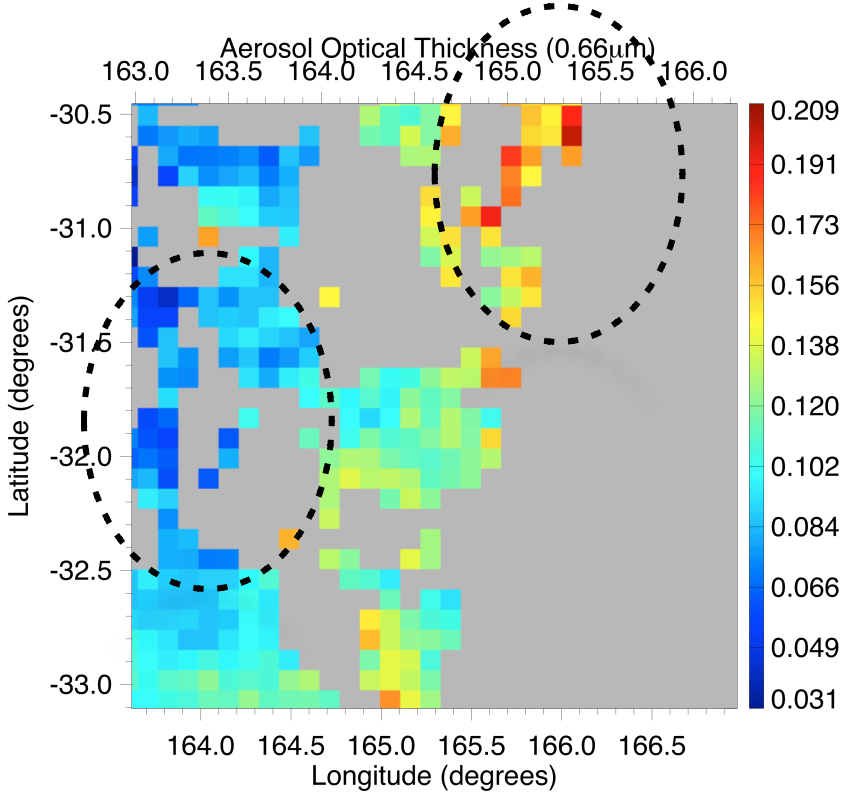
Less corrections at longer wavelengths

Original vs corrected AOT

Original (0.86μm)

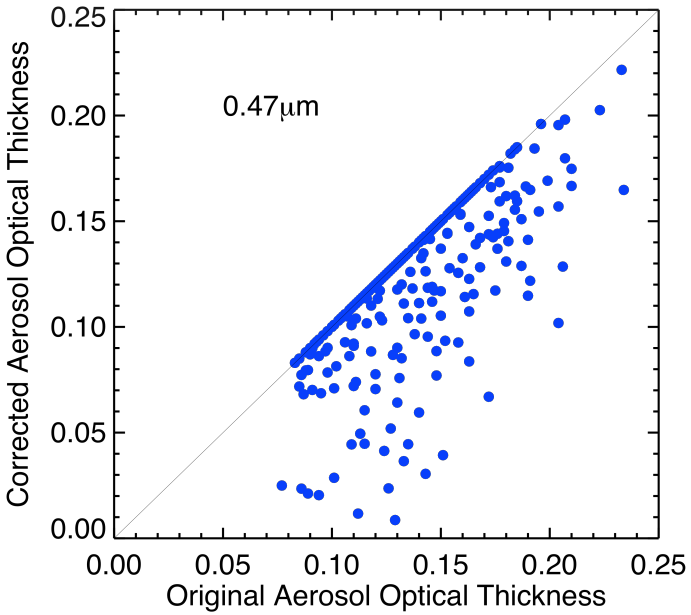


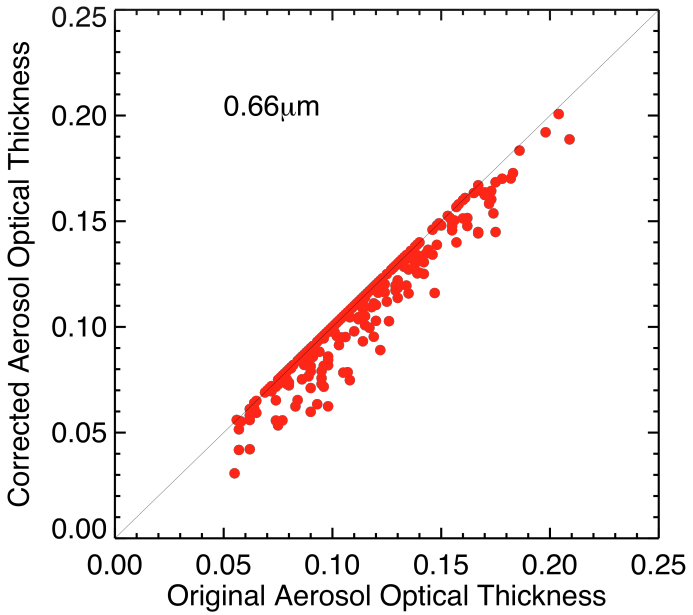
Corrected (0.86μm)

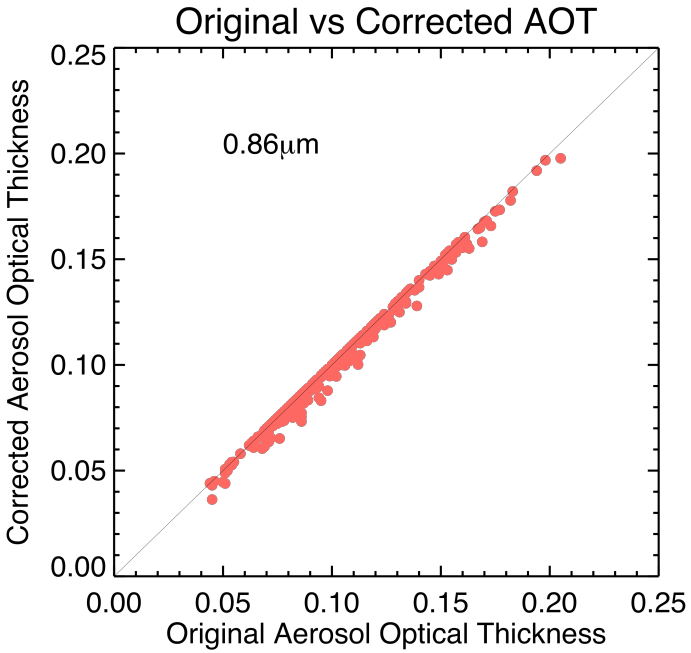


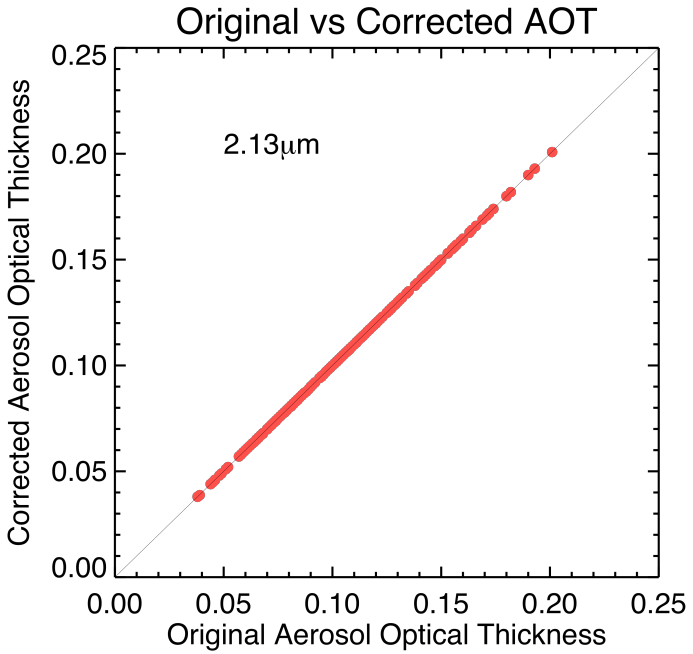
Less corrections at longer wavelengths

Original vs corrected AOT









Summary

- CERES observations can be used to correct MODIS AOT retrievals for cloud 3D radiative effects.

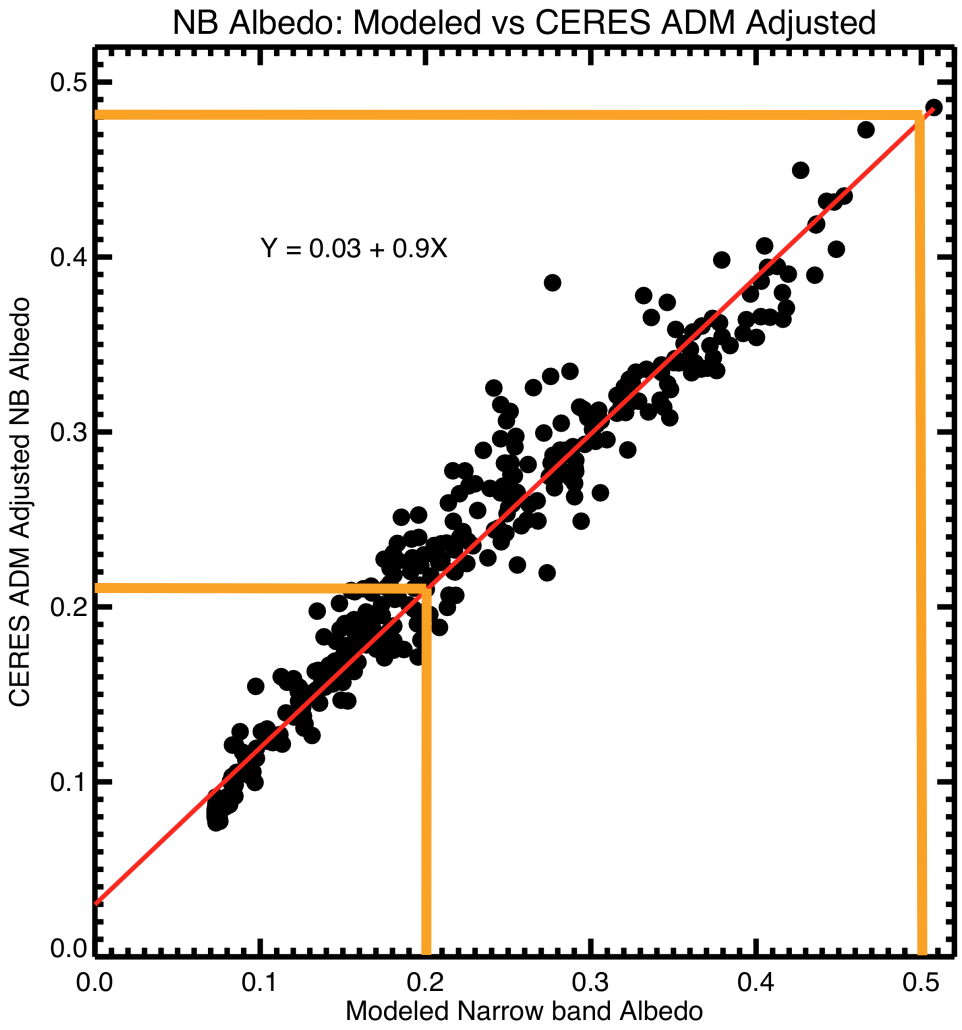
- Larger corrections (0.05-0.1) are for shorter wavelength.

- Corrections for longer wavelengths (e.g., 0.86 and 2.13 microns) are small.

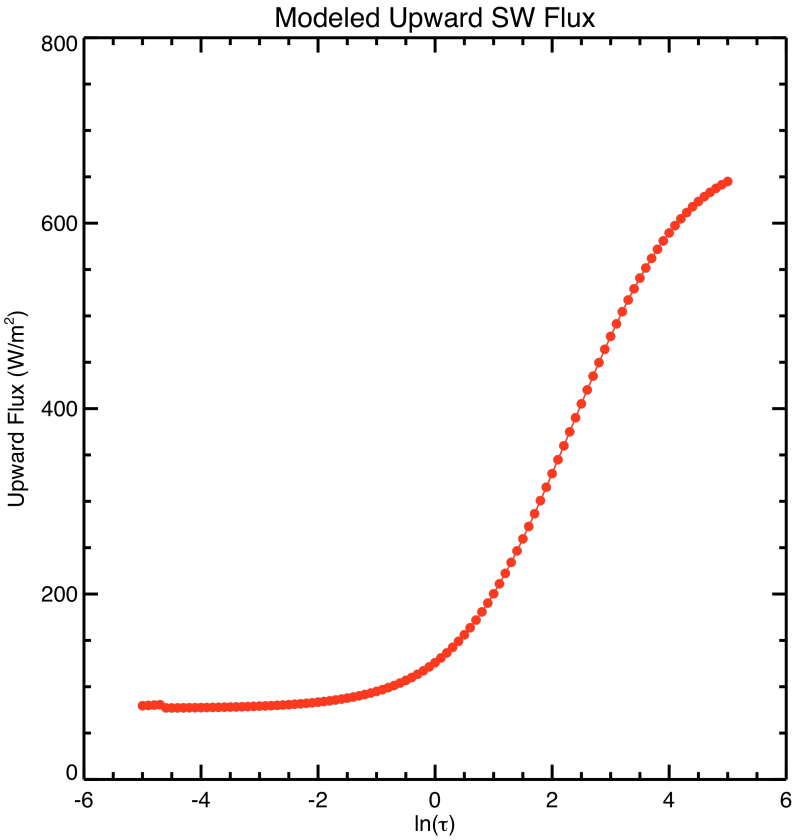
- Validation of the correction algorithm is needed.

CERES ADM Adjusted NB Albedo

1D model underestimates upward flux for optically thin and overestimate upward flux for large optically thick clouds



Modeled SW TOA Radiance



Modeled upward SW flux for water clouds θ_0=45°

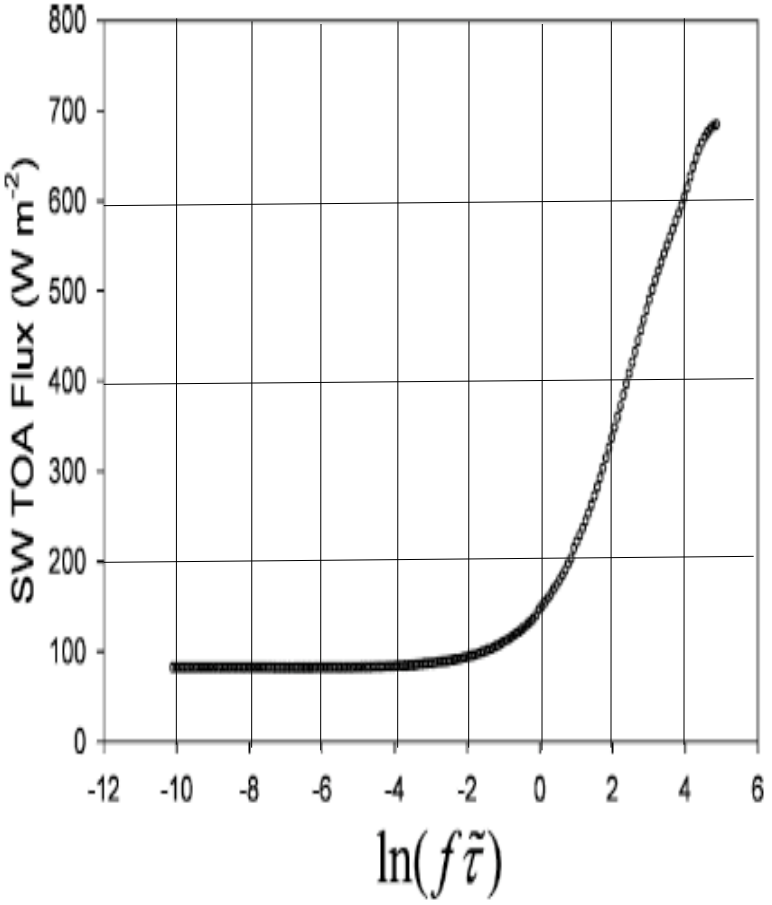


FIG. 2. TOA flux against $\ln(f\tilde{\tau})$ for liquid water clouds at θ_o = 44°–46°.

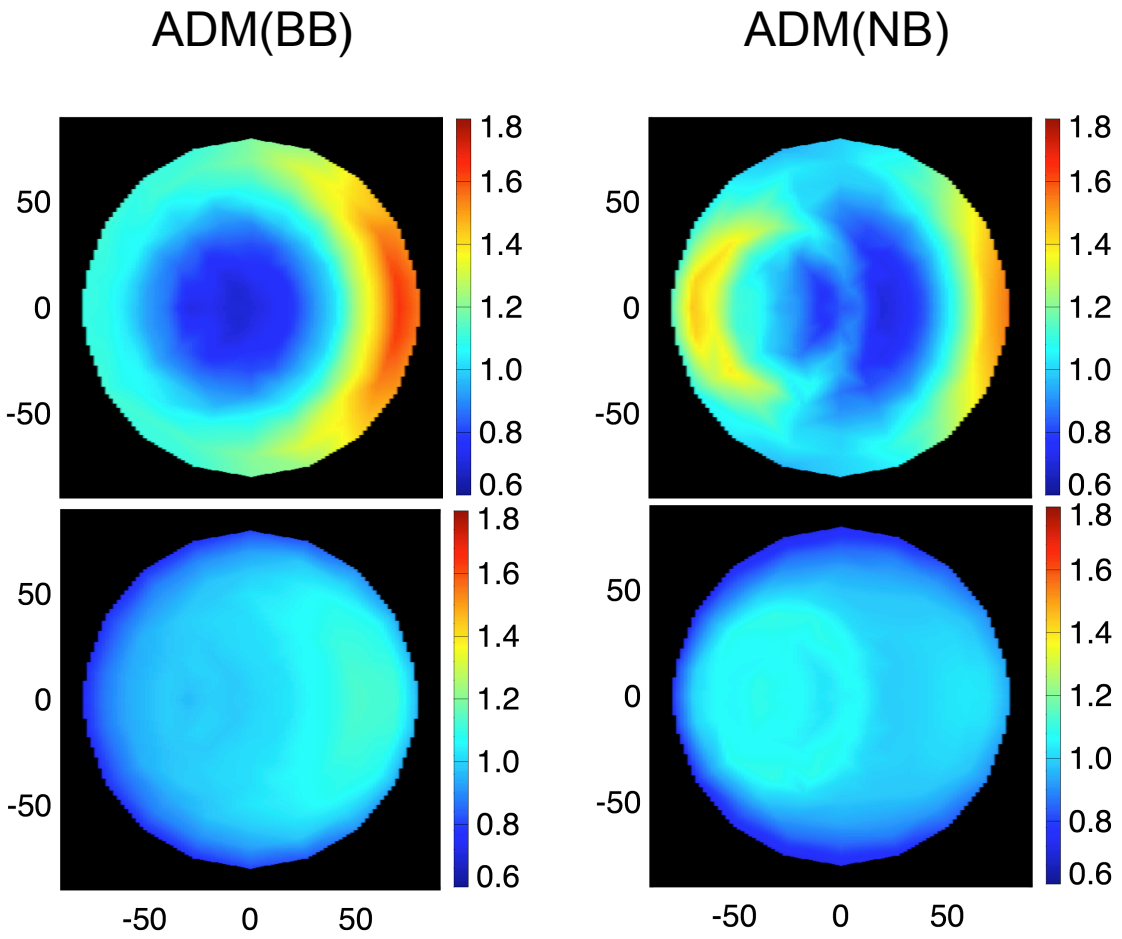
Loeb et al, 2005

Broadband and Narrowband ADMs

$ADM = \pi I/F$

τ =4

τ =20



CERE Flux cannot be directly used since ADM(BB) ≠AMD(NB)